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13. ABSTRACT (Maximum 200 words)

Appartus for measuring transient photoresponse (TPR) was designed, constructed and tested which makes it possible to explore new regimes of quasiparticle relaxation in thin films of the high Tc cuprate superconductors as well as other superconductors. As a result, the transient photresponse technique has been improved in several important ways. The photoexcitation comes from ultrafast pulses with a broad range of fluence. The covery of the recovery of the resulting nonequilibrium carrier distribution is revealed by transient voltage pulses generated in samples which have a novel and convenient Corbino-disc geometry. The measurements are made with a fast Hypres oscilloscope which probes the previously unattainable temporal regime between 10 ps less than t less than 10ns. The measurements were made on test films of the normal metals and superconducting films of niobium and c-axis $YB_2Cu_3O_7$.

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FINAL TECHNICAL REPORT

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

Contract No. F49620-88-K-0002
1 December 1987 - 30 April 1990

Detectors of Infrared Radiation Based on High T(c) Superconducting YBCO Films.

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June 1991

Final Technical Report AFOSR/SDI Contract F49620-88-K-0002

Apparatus for measuring transient photoresponse (TPR) was designed, constructed and tested which makes it possible to explore new regimes of quasiparticle relaxation in thin films of the high Tc cuprate superconductors as well as other superconductors. As a result, the transient photoresponse technique has been improved in several important ways. The photoexcitation comes from ultrafast pulses with a broad range of fluence. The recovery of the resulting nonequilibrium carrier distribution is revealed by transient voltage pulses generated in samples which have a novel and convenient Corbino- disc geometry. The measurements are made with a fast Hypres oscilloscope which probes the previously unattainable temporal regime between $10ps < t < 10ns$. The measurements were made on test films of the normal metals and superconducting films of niobium and c-axis $YBa_2Cu_3O_7$.

Below Tc the results for high quality superconducting films used show unequivocally that the relaxation is by nonthermal processes which are presently being analyzed. At Tc for both kinds of films the relaxation fits the bolometric model; it is consistent with laser heating and the temperature coefficient of resistance. Some results and preliminary analyses have been published in refs 1, 2, and 3. Further analyses and modeling of the data are being made by Dr. N. Bluzer and Dr. M. Johnson who were the scientists responsible for collecting the data. They prefer working independently and as a consequence each plans on publishing his own analysis and model. The major contribution made under the present program is the determination of a much longer than expected non-equilibrium relaxation time in the high Tc cuprate films which is not due to heating of the film, i.e., it is nonbolometric. Follow-on modeling now being undertaken is expected to shed light on the important channels which are operative in causing the relaxation.

The new method relies on the current flowing in the Corbino disc geometry shown in Fig. 1. This geometry has the advantage that there are no normal self-fields at the boundaries and thus losses due to flux flow associated with the measuring current are excluded. The experimental set-up used to make the impedance measurements over a range of temperature from 7 to 200K is shown in Fig. 2. A description of the apparatus given in ref. 1. A more complete description and analysis of the method will be published by N. Bluzer.

A series of thin films of Nb and YBa2Cu3O7 were made in which the thicknesses varied down to 100 angstroms. It was demonstrated using a thick (>2000 angstrom) film that no signal is detected as expected when the optical penetration depth is < film thickness. The films were exposed to variable fluence (0.003 to ≤ 3.0 μJ) 300 fsec 665 nm 2

KHz laser pulses which were made available in the laboratory of Prof. M. Fayer with support from another contract. The photoinduced impedance changes in the samples biased with a dc current exhibited a transient voltage signal which were recorded. Typically, the voltage signal had a sharp (<50 psec) rise followed by a more gradual decay.

A typical response for YBa2Cu3O7 is shown in Fig. 3. At T_c the photoresponse was the highest. The relaxation time constant for YBCO films on Mg0 was greater than 2 nsec and about 1 nsec for YBCO films on $LaAl0_3$. Above T_c, the relaxation voltage signal was smaller in amplitude and followed a simple exponential dependence. Unlike the results reviewed and reported elsewhere the present results yield a photo response signal well below T_c which is not due to flux flow. The response is linear with current and fluence above Tc. Below Tc the signals are linear for low fluence and currents only. The signals are relatively temperature independent from 10 K below Tc down to the lowest temperature at which the measurements were made, 7 K.

The niobium films also show a response well below Tc. Typical relaxations for a 400Å sample are shown in Fig. 4. As in the case of YBa2Cu3O7 films the photoresponse below Tc is nonbolometric. The analysis indicates a biexponential decay consistent with previous measurements of branch imbalance. [4] The faster relaxation, of the order of hundreds of picoseconds, can be interpreted in terms of the linear Rothwarf-Taylor equations. Above Tc the amplitude of the signal changes in the opposite direction with temperature as would be expected for a bolometric response and thus is anomalous and requires further investigation before it can be understood in a microscopic sense.

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1 N. Bluzer, D. K. Fork, T. H. Geballe, M. R. Beasley, M. Y. Reizer, S. R. Greenfield, J. J. Stankus, M. Fayer, "Superconducting, Transition, and Normal State Photoresponse in YBCO Observed at Different Temperatures," *IEEE Transactions on Magnetics*, **27** (2) 1519-1522.

2. M. Johnson, N. Bluzer, M. Reyzer, T. H. Geballe, S. R. Greenfield, J. J. Stankus, M. D. Fayer and C. Herring, "Photoresponse of Nb Films; Observation of Biexponential Recovery Times of the Superconducting State," *IEEE Transactions on Magnetics*, **27** (2) 1523-1527.

3. M. Johnson, M. R. Beasley, T. H. Geballe, S. R. Greenfield, J. J. Stankus and M. D. Fayer, "Anomalous Photoresponse of Metal Films," *Applied Physics Letters* **58** (6) 568-570.

4. M. Johnson and R. H. Silsbee, *Physical Review Letters*, **58**, 2806 (1987)

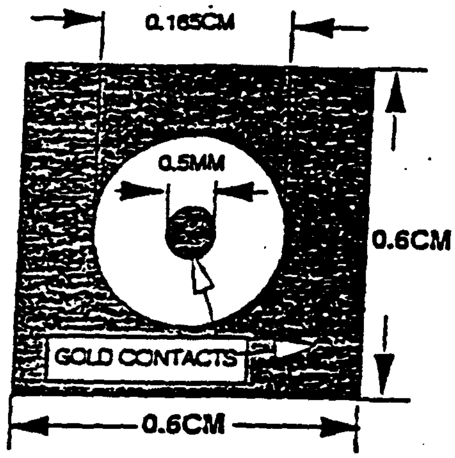

Figure 1. Corbino Disk Sample Geometry for Minimization of Fluxoids formation.

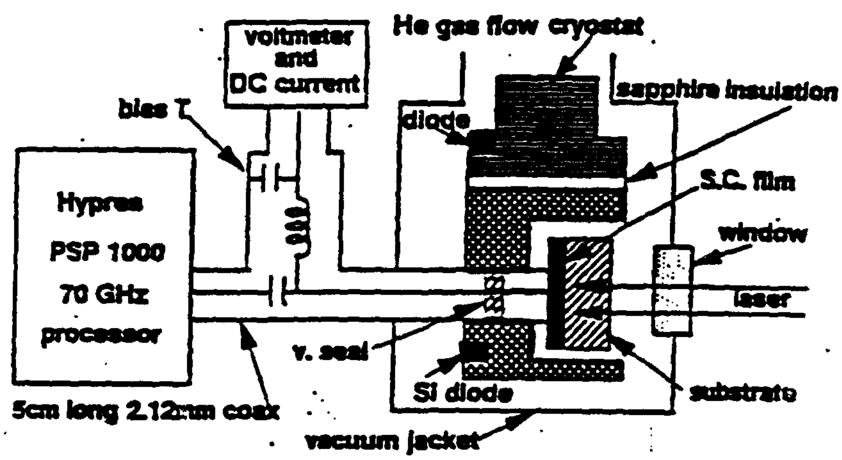

Figure 2. Experimental set-up.

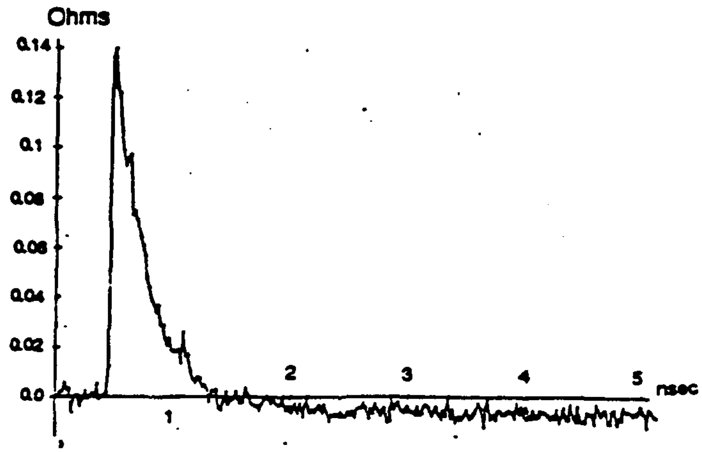

Figure 3. Photoresponse signal from a $YBa_2Cu_3O_7$ film on $LaAlO_3$ at 6.8 K biased with 20.6 mA.

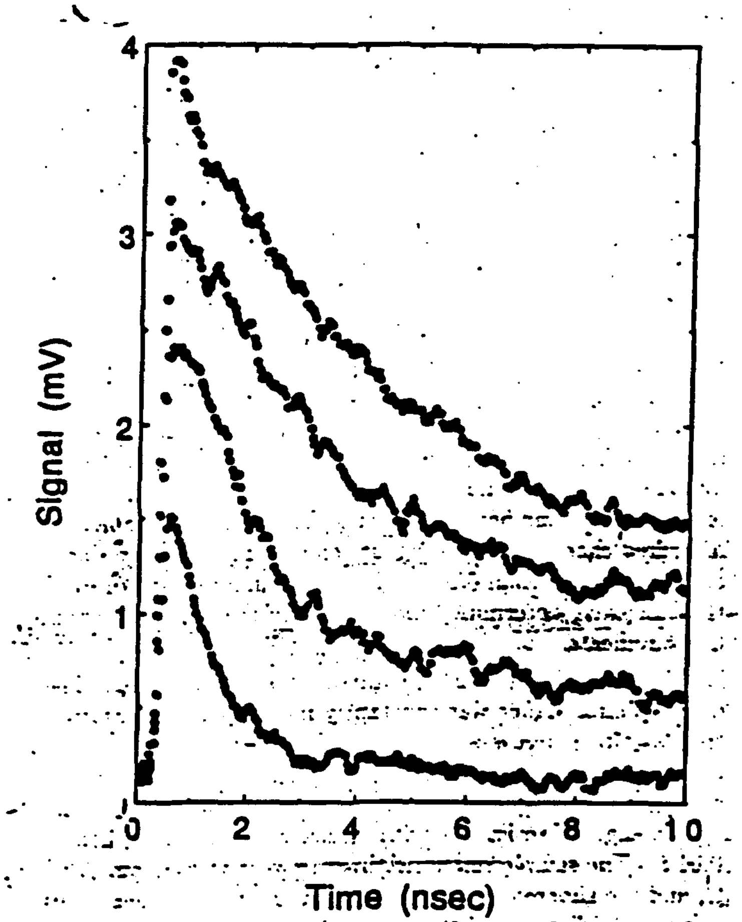

Figure 4. Examples of the signal in sample 3 (40 nm Nb on $LaAlO_3$, T_c = 8.7 K). From bottom to top the curves correspond to incident fluences of 9, 54, 225, and 900 nJ/pulse. I_b = 50 mA; T = 8.1 K.